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Contributed paper

Stability of mirror chambers and mechanics: an example of the improvement of vibrational behaviour

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ALBA synchrotron light facility includes a 3 GeV low-emittance storage ring capable of running in the top-up mode which will feed a number of beamlines. Xaloc and CIRCE are among these beamlines. These beamlines are equipped with mirrors which need high stability. There are a lot of mirror chambers in the market and we decided to improve one of them rather than developing a new one. For this purpose, the ALBA team organized a collaboration with a supplier of beamline components. ALBA did the conceptual design of the improvements, the Finite Element Analysis (FEA) optimization and the metrology tests. The supplier provided a detailed design and the production. The improvement was implemented on several mirror chambers including actuators from two to five degrees of freedom. At the beginning of the project, the hypothesis was an excitation coming from the ground lower than 1 μm for frequencies below 45 Hz and negligible above it. The strategy[0] in terms of dynamical stability was not to amplify the ground excitation below 45 Hz or around 50 Hz. That is, to increase the frequency of the system resonances above 45 Hz (excluding the range of about 50 Hz). As a result, we obtained a high level of stability for such mirror systems and we almost met the target value for the first mode of vibration.

1. Introduction

In this presentation, we describe an example of collaboration, as it gave a good compromise between the expected outcome and the cost.

The choice of the partner was based on: a high level of technicity…of course; a very high level of organization and rigour to control the performances, the schedule and the cost together (high level of project management); a high reactivity in the relationship with the customer; and the will and interest to invest manpower in a risky project including a complicated collaboration with a customer.

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2. The technical project

The stability requirement for most of the critical components in ALBA is to have a level of perturbations lower than 1 μm on the optics.

On the basis of the vibrational spectrum measured on ALBA site before the construction, the strategy was to avoid having resonances in the same area other than the main excitations. Then the criteria for designing the instruments were to remove resonances below 45 Hz, and around 50 Hz.

We did not find in the market any mirror chamber with five degrees of freedom meeting this requirement. Therefore, we decided to use a commercially available goniometer-type mirror chamber provided by IRELEC close to our specifications, with basically stiff and accurate mechanics, and to improve the weak points, increasing the stiffness of some parts and connections.

3. The improvement process

The aim of this process was to improve the performances without an increase in the manufacturing cost. We reinforced some parts of the mechanics, step by step, from the bottom to the top. For each modification we did an FEA optimization. Often, the increase of the stiffness of a part increased the weight. After several iterations of FEA, for each part, we stopped to modify when the ratio stiffness/weight was no longer increasing significantly.

The mirror chamber before improvement is shown in figure 1.

The result of the FEA on the improved design is shown in figure 2: the first mode of vibration = 46 Hz. The final design is shown in figure 3 (the new mirror chamber after improvement).

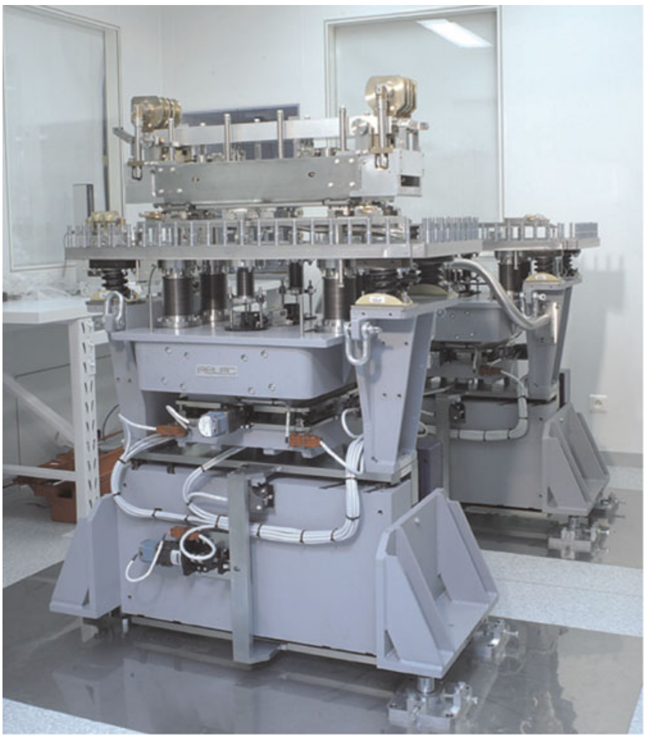

FIGURE 1. Mirror chamber before the improvement.

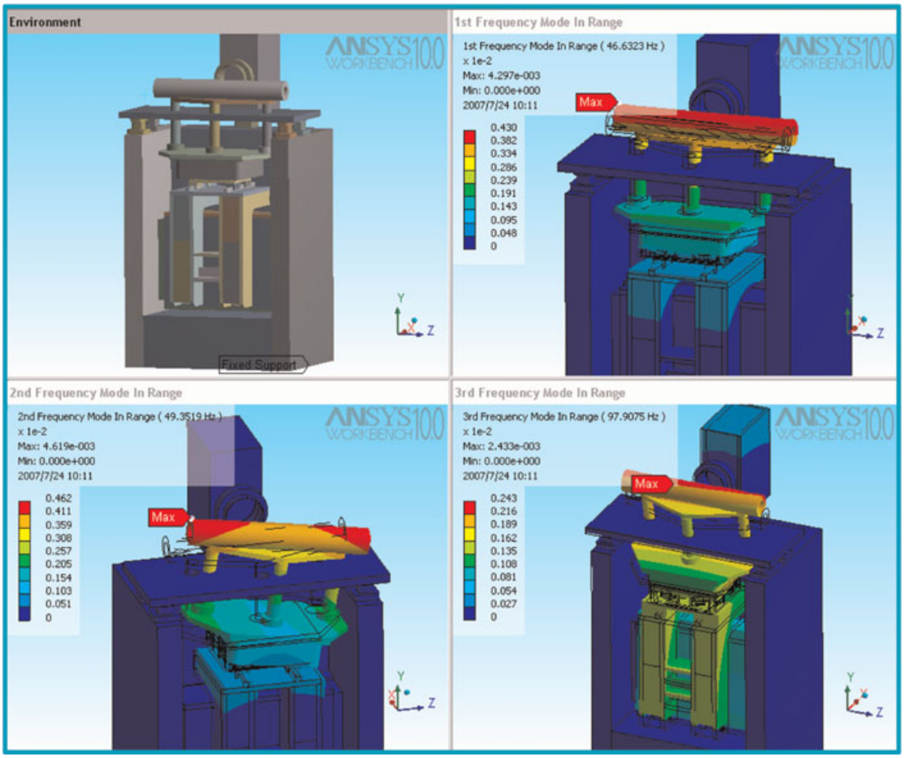

FIGURE 2. Result of the FEA on the improved design.

4. The measurements

As a part of the validation process, the motion performance of the mirror chambers has been measured including the spectrum of resonance frequencies.

The angular displacements are measured with an interferometer ML10 Gold Edition (Renishaw, UK). The interferometer optics was fixed on the mirror plate,

FIGURE 3. The new mirror chamber after improvement.

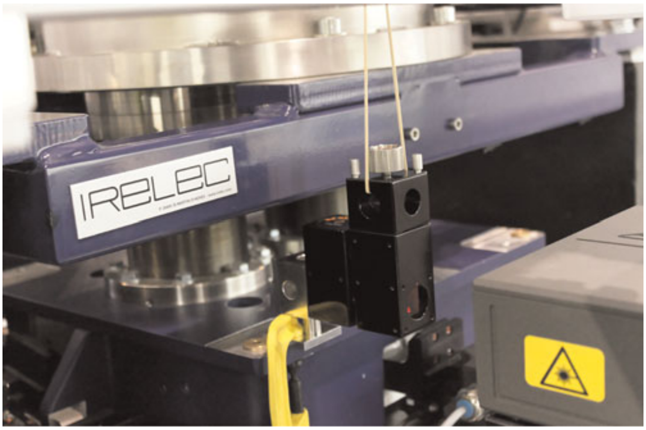

FIGURE 4. The measurement setup.

which is directly linked to the mirror. The reference is suspended with two rubber wires (very low eigen-frequency, easy to remove from the spectrum) and placed as close as possible to the optics to avoid the effect of the turbulences (the measurement set-up is shown in figure 4).

The resonances of the mirror chamber are obtained by recording the spectral response to a hammer shock. The resulting spectrum is given in figure 5. (impulse response spectrum).

One can see that the lowest resonance appears at 42.51 Hz very close to the simulation result.

Note that preloading the mechanics strongly would increase the stiffness and raise the eigen-frequencies. However, with this strategy there would be an evident risk of decreasing the resolution. The strategy followed here, on the contrary, improves stability without compromising resolution, as demonstrated with accurate metrology of the resolution (figure 6). The resolution was found to be 0.2 µrad, fulfilling the specifications.

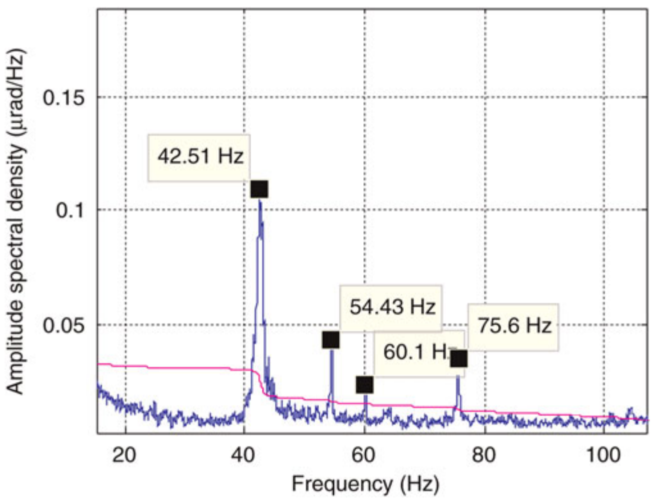

FIGURE 5. Impulse response spectrum of the mirror chamber.

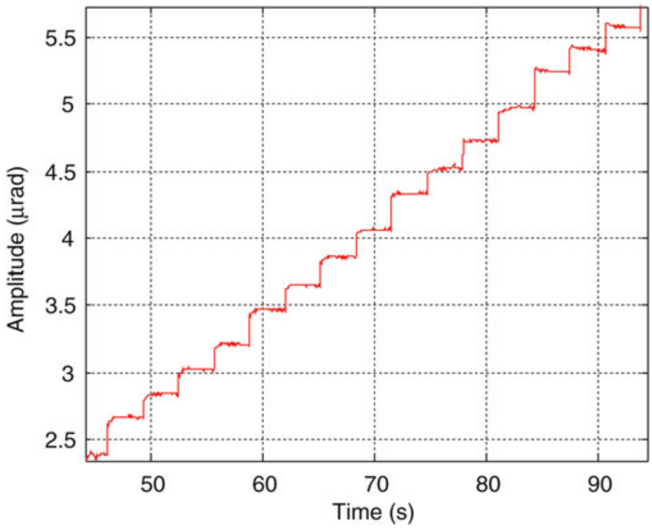

FIGURE 6. Resolution scan of the roll axis.

5. Conclusion

Technical conclusion: The first eigen-frequency at 42 Hz for a five-axis-of-freedom mirror chamber meets our specification, without decreasing the resolution.

The FEA does not give absolute values of the eigen-frequencies but indicates the weak points of the system, and is very helpful to choose the best solutions for improvement.

Economical conclusion: When there is no commercial product which satisfies our specifications, modifying the available instrument to our requirement is economically viable.